Eur J Vasc Endovasc Surg (2010) **40**, 492–498

Carotid Artery Reconstruction for Infected Carotid Patches

P.A. Naughton, M. Garcia-Toca, H.E. Rodriguez, W.H. Pearce, M.K. Eskandari, M.D. Morasch*

Division of Vascular Surgery, Northwestern University Feinberg School of Medicine, 676 North St Clair, Suite 650, Chicago, IL 60611, USA

Submitted 22 April 2010; accepted 12 July 2010
Available online 11 August 2010

KEYWORDS
Carotid endarterectomy;
Infection;
Patch;
Arterial conduit

Abstract *Objectives:* Infected carotid prosthetic patches (ICPP) are a rare but catastrophic complication of carotid endarterectomy (CEA). Prevention and appropriate surgical management is essential. We report our experience of carotid artery reconstruction for ICPP.
Design: Single-center retrospective study.
Methods: 10-year review of the surgical treatment of ICPP.
Results: Twelve patients presented with patch infection following CEA. Three patients presented acutely with an expanding hematoma, eight with chronic complications (abscess/discharging sinus $n = 5$, carotid pseudoaneurysm $n = 3$). Mean age was 75 years. Replacement conduits included superficial femoral artery ($n = 6$), cadaveric homograft ($n = 3$), long saphenous vein ($n = 2$) and one patient had primary closure. Five patients had muscle flaps fashioned for carotid artery protection. Operative complications included hypoglossal nerve injury (1 patient), superficial skin infection (2 patients) and one patient was returned to the operating room for a neck haematoma. Five surgical specimens were culture positive for: *Staphylococcus aureus* ($n = 3$), *Corynebacterium propionibacterium* ($n = 1$) and *Streptococcus anginous* ($n = 1$). There were no 30-day mortalities. Mean hospital stay was 6 days. Median follow-up was 16 months (range 3–108 months).
Conclusion: Carotid artery reconstruction in a contaminated wound represents a significant surgical challenge. Unlike previous reports that used venous conduits, this is the first series where cadaveric or autologous arterial conduits were preferred. Arterial conduits achieved durable short term follow-up.
© 2010 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.

* Corresponding author. Tel.: +1 312 9262716; fax: +1 312 6954955.
E-mail address: mmorasch@nmh.org (M.D. Morasch).

1078-5884/$36 © 2010 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.ejvs.2010.07.005

Introduction

Stroke is the third most common cause of death in the US.[1] The role of carotid endarterectomy (CEA) in stroke prevention has been the subject of intense scrutiny. Patch angioplasty has several reported advantages over primary arteriotomy closure including lower peri-operative stroke and arterial thrombosis rates and a lower incidence of recurrent stenosis on long-term follow-up.[2–4] Physicians Quality Reporting Initiatives encourage surgeons to complete CEA with a patch. The patch used may be autologous, prosthetic or animal derived, with conflicting reports of superiority.[5–7] Polytetraflouroethylene (PTFE) or Dacron are the most favoured prosthetic patches and have the advantages of being readily available, allow the greater saphenous vein to be conserved for future use and obviate the need for a groin dissection.[8] Prosthetic patch infection is rare but is one of the most feared complications following carotid patch angioplasty (Fig. 1a and b).[9–13]

Arterial conduits, either autologous or cryopreserved, are robust and appear a safer alternative for carotid reconstruction than the saphenous vein.[14,15] In this present study, the experience of a single center treating carotid patch infections using a variety of conduits with preference for arterial conduits is reported.

Patients and Methods

ICPP was defined as infection confirmed from blood or wound culture results, imaging findings and clinical presentation in the presence of implanted prosthetic graft involving the common and internal carotid artery following a previous carotid endarterectomy and patch angioplasty, consistent with the CDC definition of deep incisional surgical site infection.[16] A retrospective review was conducted for all patients who underwent surgical treatment for ICPP in our institution between December 1998 and December 2008. A total of 12 patients (nine males and three females) were identified from a prospectively collected database documenting demographics, presentation, procedure and outcome. The median age was 78 years (range 63—84 years). All patients were American Society of Anaesthesiologists (ASA) class ≥ 3. Seventy five per cent of patients had diabetes mellitus. Data collection was performed according to approved Institutional Review Board protocols.

Ten patients had the original CEA performed in an outside hospital, two were performed at our institution. Three of the patients originally operated elsewhere had early skin infections after CEA, of the two patients operated in Northwestern one had an early skin infection and one patient developed an infection from a drain site. The patch material used at CEA were; Dacron ($n = 7$), PTFE ($n = 3$), bovine pericardium ($n = 1$) and autogenous GSV ($n = 1$).

Intravenous antibiotics were administered pre-operatively and in cases of chronic infection patients were on long-term antibiotics prior to surgery. All patients underwent carotid artery duplex, computed tomography (Fig. 2) or magnetic resonance angiography (MRA), except those who presented with acute blowout and cardiovascular instability or airway compromise. In patients in whom we anticipated using autologous superficial femoral artery as conduit the superficial femoral artery was screened pre-operatively by duplex imaging in the vascular lab.

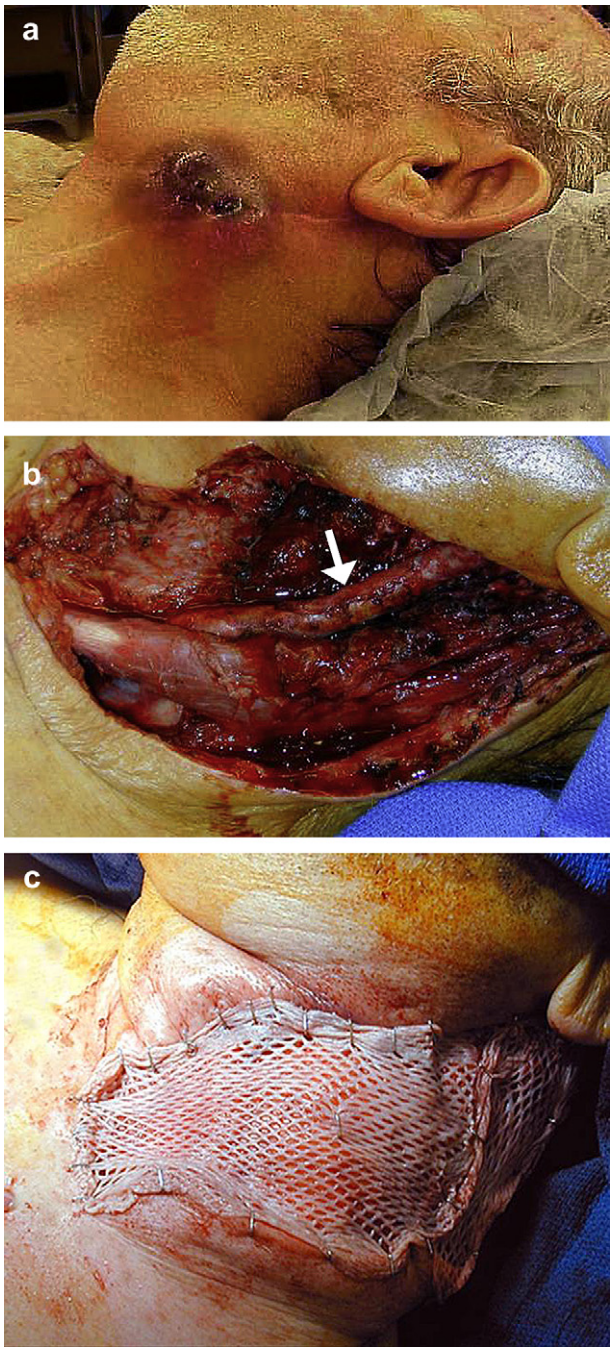

Figure 1 (a) Photograph of patient with large neck abscess and hematoma following left CEA. (b) Intra-operative photograph of ICCP. (c) Post-operative photograph following carotid artery reconstruction, coverage with muscle flap and split skin graft.

Procedure

Intra-operative tissue and graft cultures were obtained from the majority of patients. Resection of the segment of

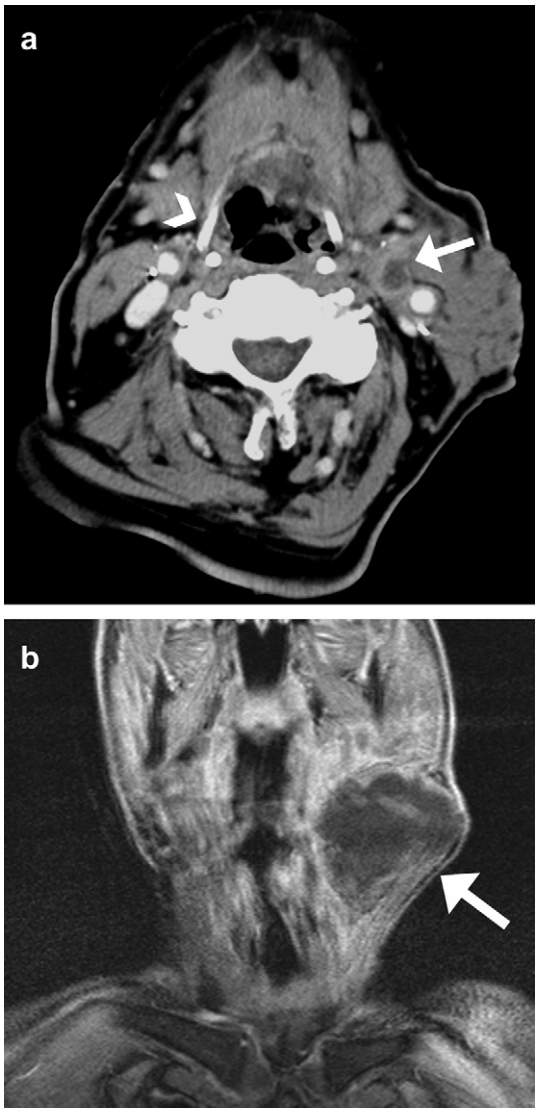

Figure 2 (a) Axial image from a CT scan, following administration of intravenous contrast, at the level of the hyoid bone (arrowhead). The image was acquired in the arterial phase of contrast administration. There is evidence of a well defined low attenuation area surrounded by an enhancing rim (arrow) in the left side of the neck anterior to the left common carotid artery. This is consistent with a small fluid collection and has imaging features of an abscess. Note the surgical clips from the prior bilateral carotid endarterectomies. (b) Coronal image from a neck MRI acquired 5 days following the initial CT scan, demonstrating a T1 fat saturation post contrast image. There is now a large, low signal, well defined collection, with an enhancing rim within the left side of the neck (arrow). This is consistent with progression and enlargement of the abscess.

carotid artery containing the infected prosthetic patch, wide debridement and vigorous irrigation with bacitracin was performed. The choice of conduit used for carotid artery reconstruction depended on the operating surgeon's preference and the patient's condition. Our concern using a venous conduit in the presence of infection or cancer is previously reported.[15] To attenuate the risk of venous degeneration we favour using a thick-walled arterial conduit. The conduits used included: superficial femoral artery (SFA) ($n = 6$), cryopreserved arterial homograft ($n = 3$), greater saphenous vein ($n = 2$) and in one patient primary closure of the arteriotomy was performed (Table 1).

The procedure of SFA harvesting and carotid artery reconstruction has been previously described.[15] In short, the neck and ipsilateral thigh were separately prepped and draped. Two separate surgical and scrub teams operated simultaneously procuring the SFA and exposing the carotid artery with the infected patch. Great care was taken to avoid cross contamination including the use of separate surgical equipment. SFA was harvested from the mid thigh and then kept in an iced bath of saline and papaverine. The harvested SFA was then reversed to achieve best size match with the carotid artery. An end to end 6 mm interposition Goretex (W.L. Gore & Associates, Flagstaff, Ariz) graft was used in the thigh to compensate for resection of this arterial conduit.

When a suitable segment of native SFA was unavailable or when patients presented acutely and a second surgical team was unavailable, cryopreserved human allografts were used for carotid artery reconstruction. Our experience with cryopreserved human allografts was recently reported.[14] A supply of cryopreserved human femoral allograft conduits (Cryolife, Inc, Kennesaw, Fla) is maintained on site. Attempts were made to match donor with recipient blood types and achieve best size match. Appropriate thawing and rinsing techniques were performed according to the distributor's instructions. No microbiological evaluation of the homografts was performed preoperatively.

In eleven patients carotid artery reconstruction was achieved by in-situ graft replacement. In one patient an extra-anatomical bypass was performed. This patient presented with a large neck abscess and carotid artery blowout. He underwent two attempted surgical interventions to treat ICPP in an outside hospital prior to his admission to our institution. Prior surgical samples grew *Klebsiella pneumonia*. In view of his significant local sepsis with a highly virulent organism and history of multiple extensive neck dissections, the surgeon performed a left subclavian artery to distal left internal carotid artery bypass, tunnelling the bypass graft (greater saphenous vein) subcutaneously, followed by ligation of the proximal left common carotid artery and extensive debridement of the neck abscess and ICPP.

In an attempt to optimise the local wound-healing environment and minimise graft exposure six patients had muscle flap coverage performed. In three patients a pectoris major flap was fashioned and in three patients the sternocleidomastoid was used. Tempero-mandibular subluxation was required to facilitate exposure of the distal internal carotid in one patient.

All patients received intravenous antibiotics post-operatively. When bacterial speciation was complete, patients received pathogen-specific antibiotics, the duration and type of antibiotics administered was directed by an infectious diseases specialist.

Table 1 Summary of patients' details who underwent carotid artery reconstruction.

Case	Primary CEA patch material	Presentation	Pre-operative bloods	Microbiology of surgical specimen	Time interval	Pre-operative imaging	Vascular conduit	Adjuvant surgery
1	GSV	Abscess	Blood culture - MRSA	MRSA	4 weeks	CT, angiogram	SFA	SCM flap
2	PTFE	Rupture	Leukocytosis	*S. aureus*	1 year	MRA	SFA	Pectoris major flap
3	Dacron	Discharging sinus	Leukocytosis	Negative	15 months	MRA, CT	SFA	Pectoris major flap
4	Dacron	Pseudoaneurysm	Leukocytosis	Negative	4 years	MRA	SFA	None
5	Dacron	Pseudoaneurysm	Normal	Negative	1 year	MRA	GSV	Tempero-mandibular subluxation
6	Dacron	Abscess	Leukocytosis	MRSA	5 days	None	Primary	SCM flap
7	Dacron	Abscess	Blood Culture — *Enterococcus faecalis*	None received	3 months	MRA	homograft	None
8	PTFE	Pseudoaneurysm	Leukocytosis	None received	13 years	CT, angiogram	Homograft	None
9	Dacron	Rupture	Blood Culture — *S. aureus*	Negative	1 year	None	SFA	Pectoris major flap
10	Bovine Pericardium	Rupture	Blood Culture — *S. Aureus*	Negative	3 months	None	GSV	None
11	Dacron	Discharging sinus	Leukocytosis	*Corynebacterium propionibacterium*	5 months	CT	Homograft	None
12	PTFE	Abscess	Leukocytosis	*Streptococcus anginous*	1 month	MRA	SFA	SCM flap

Follow-up protocol

Patients were evaluated at 1 month, 6 months and annually thereafter with duplex ultrasonography and clinical examination.

Results

Presentation

The median time interval from CEA to surgical reconstruction for ICCP was 1 year (range 6 days—13 years). Six patients (50%) presented with an abscess or discharging sinus, three (25%) with a carotid artery pseudoaneurysm and three (25%) with carotid artery blowout. Four of the nine patients referred from outside hospitals underwent a total of 7 operations prior to carotid artery reconstruction in our department.

Outcome

There was no 30 day mortality. One patient required surgical re-exploration for bleeding. This patient underwent carotid artery reconstruction for ICPP in an outside hospital with Goretex interposition graft but developed a large mycotic aneurysm one month post-operatively. Operative specimens from the other hospital were positive for Methicillin resistant *Staphylococcus aureus* (MRSA). In the interval he sustained a stroke from suspected septic cerebral emboli. Under our care, he underwent carotid reconstruction using an SFA conduit and a large abscess cavity was debrided. Twelve days post-operatively he developed a rapidly expanding neck hematoma. He was urgently returned to the operating room. The source of bleeding was the site of anastomosis of the external carotid artery to the SFA conduit. This was repaired, the external carotid artery was ligated, and antegrade flow maintained into the ICA. A second patient, who had superficial femoral artery harvested, needed evacuation of a groin seroma.

There were no peri-operative strokes. Two patients sustained cranial nerve injury. One patient presented with a large neck abscess. This 84 year old diabetic male underwent incision and drainage of a neck abscess in an outside hospital prior to his referral to our department. At surgery he was noted to have a large inflammatory process that incorporated the hypoglossal nerve. The nerve was sacrificed. The patient made satisfactory progress with physiotherapy. The second patient was noted to have hoarseness that had nearly completely resolved at six month follow-up.

Median hospital stay was six days. No patient during inpatient stay or follow-up was diagnosed with or treated for re-infection of the carotid artery. In addition, none of the patients that had their native SFA harvested required further intervention for peripheral arterial disease during follow-up.

Microbiology

Five surgical specimens were culture positive for: MRSA ($n = 2$), *Staphylococcus aureus* ($n = 1$), *Corynebacterium Propionibacterium* ($n = 1$) and *Streptococcus anginous* ($n = 1$). Five surgical samples had negative cultures and in 2 patients no sample was received in the microbiology laboratory.

Follow-up

The median follow-up was 16 months (range 3—108 months). Ten patients attended follow-up for a minimum of six months. One patient died from the sequelae of infective endocarditis 6 months post-operatively. There were three other deaths on follow-up unrelated to infected carotid patch. No patients had radiological or clinical evidence of carotid re-infection or graft occlusion on follow-up.

Discussion

Infection of patches following carotid endarterectomy represents a rare but significant surgical challenge. The incidence of patch infection is 0.25—0.5% of all carotid endarterectomies, a slightly higher incidence is reported when prosthetic patches are used.[6,10] Seventy-seven cases are reported in literature.[17] Clinical presentation is diverse ranging from an asymptomatic pseudoaneurysm to patch rupture. Knight et al.[17] in a review article including 77 cases of carotid patch infections report 33% of cases presented with pseudoaneurysm, 30% with a local draining sinus and 24% with neck swelling.

Time of presentation has a bimodal distribution.[18] Naylor et al.[10] in a comprehensive review report 37% of cases presented within 2 months of surgery, while 56% presented 6 months after surgery. Early presentation may be related to post-operative wound haematoma or skin infection. Bacteriological culture from the operative field indicate that early presentation is associated with virulent organisms (MRSA, Gram negative bacteria) while late presentation may result from less virulent skin commensals (*Staphylococcus epidermidis*).[10,13] In this present study the majority of patients were referred to our service after unsuccessful surgical reintervention or prolonged antibiotic treatment. As a result, most patients ($n = 7$) were treated 6 months after CEA and presented with chronic abscess or discharging sinus. Prolonged pre-operative antibiotic regimen may also explain why surgical specimens were negative in four patients.

Surgery for infected prosthetic grafts has an alarmingly high morbidity and mortality. The principles of surgical management of this complication include eradication of the septic focus and revascularization. The complexity in treating aortic graft infection (AGI) is well reported; revascularization may be achieved with an extra-anatomical bypass or in-situ graft replacement.[14,19—23] In-situ graft replacement may be established using a variety of conduits; antibiotic soaked synthetic graft, cryopreserved human allografts or autogenous vein.[14,20—23] While the principles governing treatment of AGI pertain to carotid prosthetic patch infection, the experience of carotid artery reconstruction for prosthetic patch infection is limited. While the need for wide debridement with meticulous dissection and preservation of nerves is intuitive, the need for revascularization is also clear. El-Sabrout and

Cooley[11] report a mortality and major stroke rate of 9–12% for surgical reconstruction, compared to 50% mortality after carotid artery ligation. To date, most favour using autologous vein as the conduit in carotid artery reconstruction. Concern exists regarding the risk of catastrophic vein graft blowout in a contaminated surgical wound.[12]

Redo carotid surgery for recurrent stenosis is associated with a higher incidence of blood loss, stroke and nerve injury compared to primary CEA.[24] In addition to scar tissue distorting planes of dissection, accessibility of the distal internal carotid artery may contribute to the difficulty of reoperation. In a series of 64 consecutive patients undergoing redo CEA in the Henry Ford Hospital, Detroit, mandibular subluxation was employed in 17% of patients.[25] In the presence of local sepsis, the surgical challenge is multiplied.

To date carotid artery reconstruction for ICPP is performed using either prosthetic graft or autologous vein. The use of prosthetic graft in the presence of infection appears counter-intuitive. In the second largest series of ICPP involving 13 patients, a synthetic patch was used in 6 patients.[11] Three (50%) of these patients had re-infection of the Dacron patch and 1 died from blowout. Autologous vein is the preferred material of reconstruction. Harvesting the vein from the groin is preferred to ankle veins due to an unacceptably high incidence of rupture.[26] Reconstruction with a vein patch or interposition graft is controversial. In a series of 8 patients from Cleveland, Rizzo et al.[9] state that in their experience a synthetic patch infection is confined to the patch itself and therefore can be managed safely by replacing the infected patch with a new vein patch. Their results support this practise. However in the presence of an abscess or purulent tissue enveloping the whole artery this patch replacement may not be sufficient. Despite adequate results, replacing the carotid artery with a thin walled vein, in a recently infected field, is a source of concern. Ascuitto et al.[12] report 6 patients treated for prosthetic infections, 5 with an interposition vein grafting and one with vein patch plasty. Two patients (33%) (1 vein interposition and 1 vein patch) had re-infection during their hospital stay requiring further surgical reconstruction.

In addition to the risk of vein graft blowout, there is evidence of injury to the intima of vein graft in the presence of active infection. This may result in early graft failure due to loss of smooth muscle relaxation followed by myointimal hyperplasia and fibrosis.[27] Lauder et al.,[28] in a series of patients who had a carotid artery bypass for an array of indications using the greater saphenous vein as conduit, report that 7 of the 46 patients available for follow-up had severe stenosis (>70 per cent) or occlusion of the bypass 18 months post-operatively. Arterial conduits are an appealing alternative to veins. Following two carotid blowouts when the greater saphenous vein was used for carotid artery reconstruction, Sessa et al.[15] opted to reconstruct with autogenous superficial femoral artery. They hypothesised that the more robust walled artery was a safer alternative to vein. Thirty patients with neck malignancy invading the carotid artery underwent resection of the carotid artery and replacement with SFA. Despite a 43% incidence of wound problems including a 30% incidence of fistula between the aero-digestive tract and skin there was no reported graft infection or carotid blowout. More recently, cryopreserved human allografts (CHA) have been used successfully for arterial reconstruction in primary arterial or prosthetic graft infection.[14,21,22] CHA have the obvious benefit of providing the durability of an arterial conduit while preserving the SFA and preventing the short term and long-term risks associated with harvesting the SFA and replacing it with a prosthetic graft.

In this present study a variety of techniques were adopted but our preference was to reconstruct the carotid artery with an arterial conduit. Choice of arterial conduit, SFA or CHA depended on surgeon preference and the clinical status of the patient. One patient required reintervention for bleed but this was due to technical issues rather than re-infection. We had no incidence of mortality, major stroke or re-infection.

For such a complex condition a multidisciplinary approach ensures optimum results. Appropriate pre-operative imaging equips the surgeon with information concerning cerebral perfusion and local involvement of infection which is crucial when planning surgical intervention. Assistance from experienced anaesthiologists and microbiologists is essential. Intra-operatively, in this present series plastic surgeons performed muscle flap coverage in six patients to improve the local wound-healing environment. Muscle flaps assist healing and infection control by increasing local blood flow thereby augmenting delivery of antibiotic agents into the area of infection and provide an ideal base for a skin graft. In our experience these adjunctive measures improve outcome.[29]

While results are encouraging there are limitations in this study. Firstly it is limited by the fact it is a single center, retrospective study with a small patient number. However, the twelve patients involved in this series represent 15% of all reported cases in the literature. Secondly due to our status as a major regional referral center, important information concerning original surgery and peri-operative management as well as follow-up data was unavailable. Thirdly our median follow-up is only 16 months (range 3–108 months). Clearly longer follow-up is necessary to determine if these encouraging short term results are sustained. Finally, a surgical specimen of two patients was not received in the laboratory for microbiological evaluation, however, both patients were included in the study because they had clinical and radiological evidence of ICPP.

In conclusion, carotid artery reconstruction represents a significant surgical challenge. This is the first series where cadaveric or autologous arterial conduits were preferred for carotid artery reconstruction for ICPP. Our unique experience with CHA and double-teaming for harvesting SFA enabled us to perform surgery and restore cerebral perfusion with a conduit resistant to re-infection in an organised and expedient manner. Arterial conduits achieved durable results with low re-infection rates. A multicenter study with longer follow-up is warranted to confirm if arterial conduits confer durable results.

Conflict of Interest

None.

Funding

None.

References

1 Rosamond W, Flegal K, Friday G, Furie K, Go A, Greenlund K, et al. Heart disease and stroke statistics — 2007 update: a report from the American Heart Association Statistics Committee and stroke Statistics Subcommittee. *Circulation* 2007;**115**:e69—171.

2 Eikelboom BC, Ackerstaff RG, Hoeneveld H, Ludwig JW, Teeuwen C, Vermeulen FE, et al. Benefits of carotid patching: a randomized study. *J Vasc Surg* 1988;**7**:240—7.

3 Rerkasem K, Rothwell PM. Patches of different types for carotid patch angioplasty. *Cochrane Database Syst Rev* 2010;**3**: CD000071.

4 Moore WS, Kempczinski RF, Nelson JJ, Toole JF. Recurrent carotid stenosis: results of the asymptomatic carotid atherosclerosis study. *Stroke* 1998;**29**:2018—25.

5 AbuRahma AF, Khan JH, Robinson PA, Saiedy S, Short YS, Boland JP, et al. Prospective randomized trial of carotid endarterectomy with primary closure and patch angioplasty with saphenous vein, jugular vein, and polytetrafluoroethylene: perioperative (30-day) results. *J Vasc Surg* 1996;**24**:998—1006.

6 Hayes PD, Allroggen H, Steel S, Thompson MM, London NJ, Bell PR, et al. Randomized trial of vein versus Dacron patching during carotid endarterectomy: influence of patch type on postoperative embolization. *J Vasc Surg* 2001;**33**:994—1000.

7 O'Hara PJ, Hertzer NR, Mascha EJ, Krajewski LP, Clair DG, Ouriel K. A prospective, randomized study of saphenous vein patching versus synthetic patching during carotid endarterectomy. *J Vasc Surg* 2002;**35**:324—32.

8 Bond R, Rerkasem K, Naylor AR, Aburahma AF, Rothwell PM. Systematic review of randomized controlled trials of patch angioplasty versus primary closure and different types of patch materials during carotid endarterectomy. *J Vasc Surg* 2004;**40**: 1126—35.

9 Rizzo A, Hertzer NR, O'Hara PJ, Krajewski LP, Beven EG. Dacron carotid patch infection: a report of eight cases. *J Vasc Surg* 2000;**32**:602—6.

10 Naylor AR, Payne D, London NJ, Thompson MM, Dennis MS, Sayers RD, et al. Prosthetic patch infection after carotid endarterectomy. *Eur J Vasc Endovasc Surg* 2002;**23**:11—6.

11 El-Sabrout R, Reul G, Cooley DA. Infected postcarotid endarterectomy pseudoaneurysms: retrospective review of a series. *Ann Vasc Surg* 2000;**14**:239—47.

12 Asciutto G, Geier B, Marpe B, Hummel T, Mumme A. Dacron patch infection after carotid angioplasty. A report of 6 cases. *Eur J Vasc Endovasc Surg* 2007;**33**:55—7.

13 Rockman CB, Su WT, Domenig C, Lamparello PJ, Adelman MA, Jacobowitz GR, et al. Postoperative infection associated with polyester patch angioplasty after carotid endarterectomy. *J Vasc Surg* 2003;**38**:251—6.

14 Brown KE, Heyer K, Rodriguez H, Eskandari MK, Pearce WH, Morasch MD. Arterial reconstruction with cryopreserved human allografts in the setting of infection: a single-center experience with midterm follow-up. *J Vasc Surg* 2009;**49**:660—6.

15 Sessa CN, Morasch MD, Berguer R, Kline RA, Jacobs JR, Arden RL. Carotid resection and replacement with autogenous arterial graft during operation for neck malignancy. *Ann Vasc Surg* 1998;**12**:229—35.

16 Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control* 2008 Jun;**36**(5):309—32.

17 Knight BC, Tait WF. Dacron patch infection following carotid endarterectomy: a systematic review of the literature. *Eur J Vasc Endovasc Surg* 2009;**37**:140—8.

18 Krishnan S, Clowes AW. Dacron patch infection after carotid endarterectomy: case report and review of the literature. *Ann Vasc Surg* 2006;**20**:672—7.

19 Seeger JM, Pretus HA, Welborn MB, Ozaki CK, Flynn TC, Huber TS. Long-term outcome after treatment of aortic graft infection with staged extra-anatomic bypass grafting and aortic graft removal. *J Vasc Surg* 2000;**32**:451—9.

20 Bandyk DF, Novotney ML, Back MR, Johnson BL, Schmacht DC. Expanded application of in situ replacement for prosthetic graft infection. *J Vasc Surg* 2001;**34**:411—9.

21 Lesèche G, Castier Y, Petit MD, Bertrand P, Kitzis M, Mussot S, et al. Long-term results of cryopreserved arterial allograft reconstruction in infected prosthetic grafts and mycotic aneurysms of the abdominal aorta. *J Vasc Surg* 2001;**34**:616—22.

22 Noel AA, Gloviczki P, Cherry Jr KJ, Safi H, Goldstone J, Morasch MD, et al. Abdominal aortic reconstruction in infected fields: early results of the United States cryopreserved aortic allograft registry. *J Vasc Surg* 2002;**35**:847—52.

23 Clagett GP, Valentine RJ, Hagino RT. Autogenous aortoiliac/femoral reconstruction from superficial femoral-popliteal veins: feasibility and durability. *J Vasc Surg* 1997;**25**:255—66.

24 AbuRahma AF, Jennings TG, Wulu JT, Tarakji L, Robinson PA. Redo carotid endarterectomy versus primary carotid endarterectomy. *Stroke* 2001;**32**:2787—92.

25 Cho JS, Pandurangi K, Conrad MF, Shepard AS, Carr JA, Nypaver TJ, et al. Safety and durability of redo carotid operation: an 11-year experience. *J Vasc Surg* 2004;**39**:155—61.

26 Tawes Jr RL, Treiman RL. Vein patch rupture after carotid endarterectomy: a survey of the Western Vascular Society members. *Ann Vasc Surg* 1991;**5**:71—3.

27 Davies MG, Kim JH, Dalen H, Makhoul RG, Svendsen E, Hagen PO. Reduction of experimental vein graft intimal hyperplasia and preservation of nitric oxide-mediated relaxation by the nitric oxide precursor L-arginine. *Surgery* 1994;**116**: 557—68.

28 Lauder C, Kelly A, Thompson MM, London NJ, Bell PR, Naylor AR. Early and late outcome after carotid artery bypass grafting with saphenous vein. *J Vasc Surg* 2003;**38**:1025—30.

29 Morasch MD, Sam 2nd AD, Kibbe MR, Hijjawi J, Dumanian GA. Early results with use of gracilis muscle flap coverage of infected groin wounds after vascular surgery. *J Vasc Surg* 2004; **39**:1277—83.